Forum for Electromagnetic Research Methods and Application Technologies (FERMAT)

Broadband Hybrid Water Antennas

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Abstract— A broadband hybrid water antenna at very high frequency band is presented. The proposed antenna is composed of a seawater monopole and a distilled-water ring antenna. The broadband of this hybrid antenna is caused by the multiple resonances introduced by the hybrid monopole-ring structure. This antenna achieves a wide bandwidth from 52.5MHz to 162.5MHz, indicating over 3.1:1 operating bandwidth, i.e., more than 102% impedance bandwidth around the center frequency of the band. The bandwidth of this water antenna can be also improved by changing the shape of the distilled-water antenna, as much as 129% impendence bandwidth with conical-shaped water antenna has been demonstrated.

Keywords—water antenna; hybrid antenna; monopole; ring antenna; broadband.

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Qing-Xin Chu (M'99–SM'11) received the B.S., M.E., and Ph.D. degree in electronic engineering from Xidian University, Xi'an, Shaanxi, China, in 1982, 1987, and 1994, respectively.

He is currently a chair professor with the School of Electronic and Information Engineering, South China University of Technology. He is also the director of the Research Institute of Antennas and RF Techniques of the university, the chair of the Engineering Center of Antennas and RF Techniques of Guangdong Province. He is also with Xidian University as a distinguished professor in Shaanxi Hundred-Talent Program since 2011. From Jan. 1982 until Jan. 2004, he was with the School of Electronic Engineering, Xidian University, and since 1997, he was a professor and the vice dean of the School of Electronic Engineering, Xidian University.

He is the foundation chair of IEEE Guangzhou AP/MTT Chapter, the senior members of IEEE and the China Electronic Institute (CEI). He has published over 300 papers in journals and conferences, which were indexed in SCI more than 1500 times. One of his papers published in IEEE Transactions on Antennas and Propagations in 2008 becomes the top ESI (Essential Science Indicators) paper within 10 years in the field of antenna (SCI indexed self-excluded in the antenna field ranged top 1%). In 2014, he was elected as the highly cited scholar by Elsevier in the field of Electrical and Electronic Engineering. He has authorized more than 30 invention patents of China.

He was the recipient of the Science Award by Guangdong Province in 2013，the Science Awards by the Education Ministry of China in 2008 and 2002, the Fellowship Award by Japan Society for Promotion of Science (JSPS) in 2004, the Singapore Tan Chin Tuan Exchange Fellowship Award in 2003, the Educational Award by Shaanxi Province in 2003.

His current research interests include antennas in wireless communication, microwave filters, spatial power combining array, and numerical techniques in electromagnetics.

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4th APCAP, July 2, 2015, Bali Island

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Outline

- Introduction
- Design of Antennas
  - hybrid water monopole-ring antenna
  - hybrid water monopole-conical antenna
  - hybrid water antenna for easy fabrication
  - hybrid water antenna with same material
- Conclusion

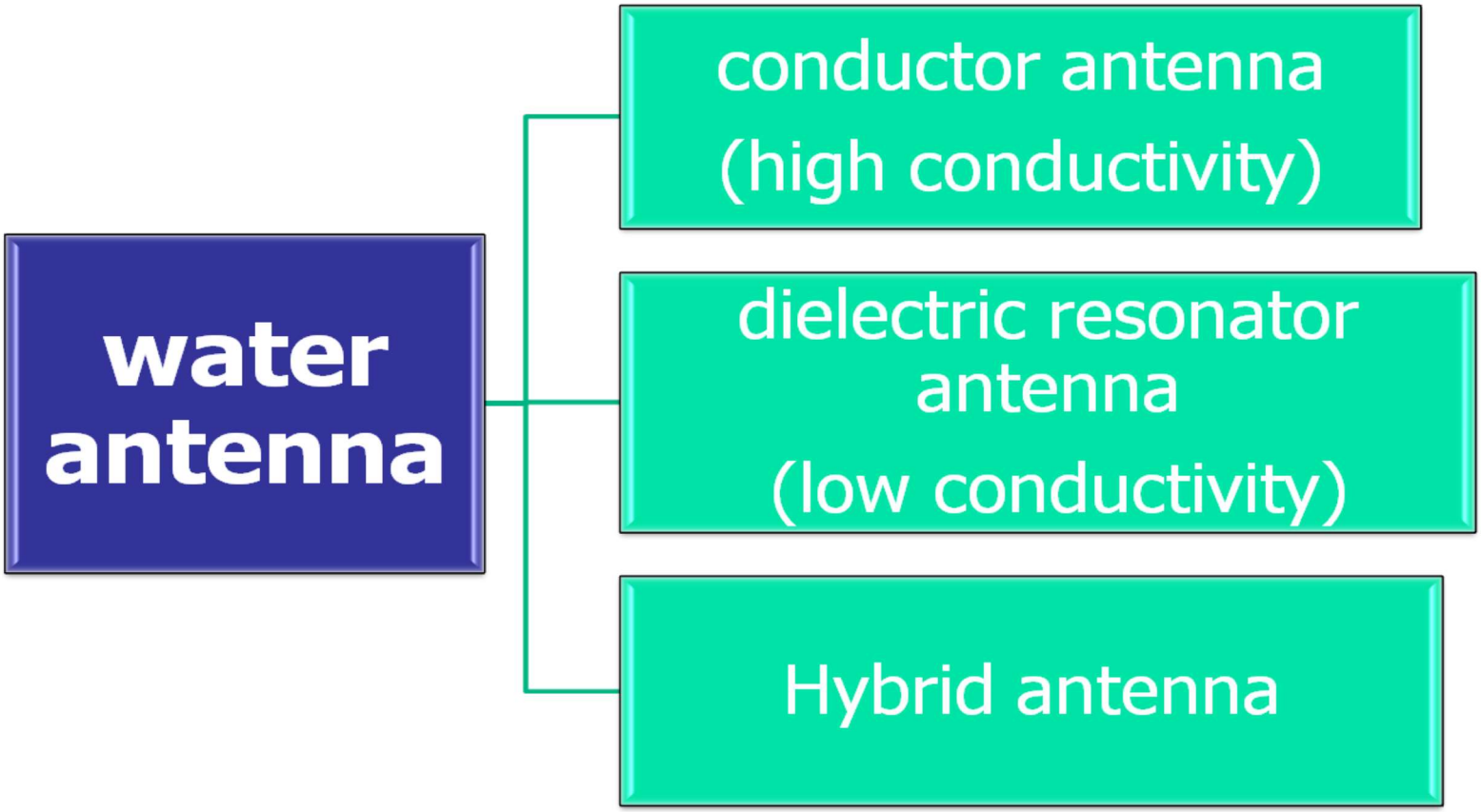
I. Introduction

Advantages of water antennas

- Fluidity
- High dielectric constant for compact antenna
- Small RCS
- Reconfigurable
- improvement in electromagnetic coupling
- low-cost

I. Introduction (cont.)

Kinds of water antennas

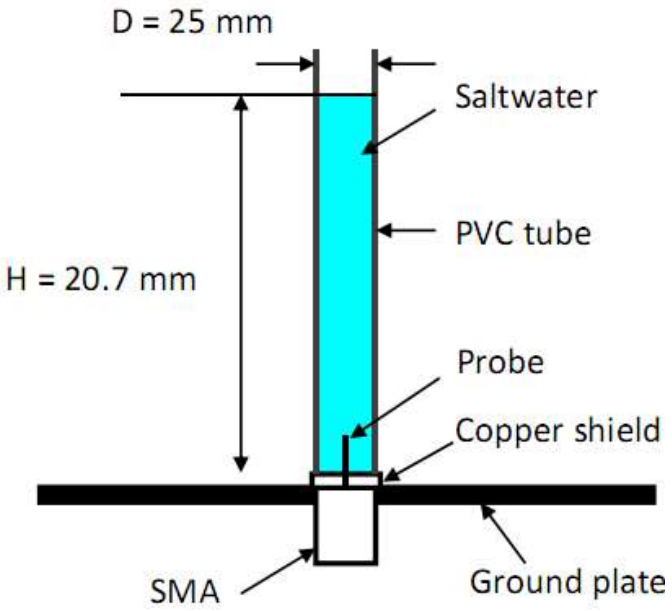


I. Introduction (cont.)

I. Introduction (cont.)

Methods of improving the impedance bandwidth

- **Add salt into pure water**



bandwidth ~10%

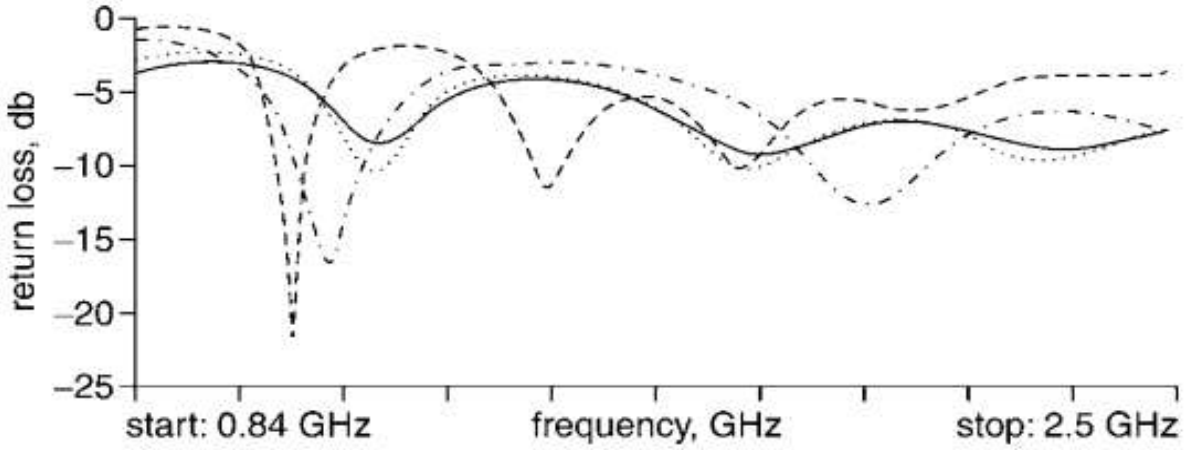


Fig. 4 *Measured return loss for different concentrations ranging from 1 to 6 ppt*

PVC tube diameter 50 mm, liquid height 20 mm

--- $S = 1$ ppt

-·-·- $S = 2$ ppt

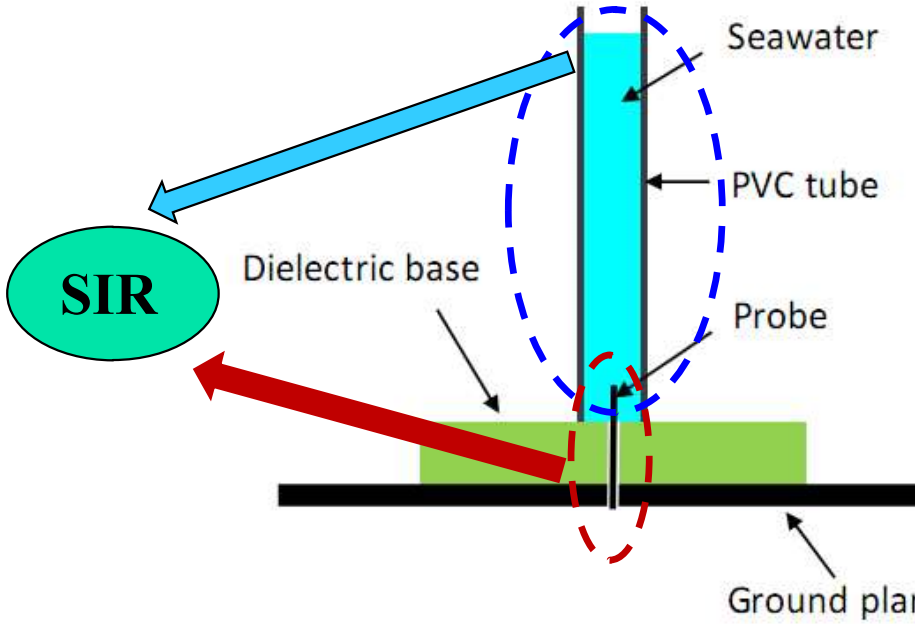
····· $S = 4$ ppt

—— $S = 6$ ppt

[1] H. Fayad and P. Record, "Broadband liquid antenna," Electronics Letters, vol. 42, pp. 133-134, 2006.

I. Introduction (cont.)

- **Insert a dielectric base between the water and ground**



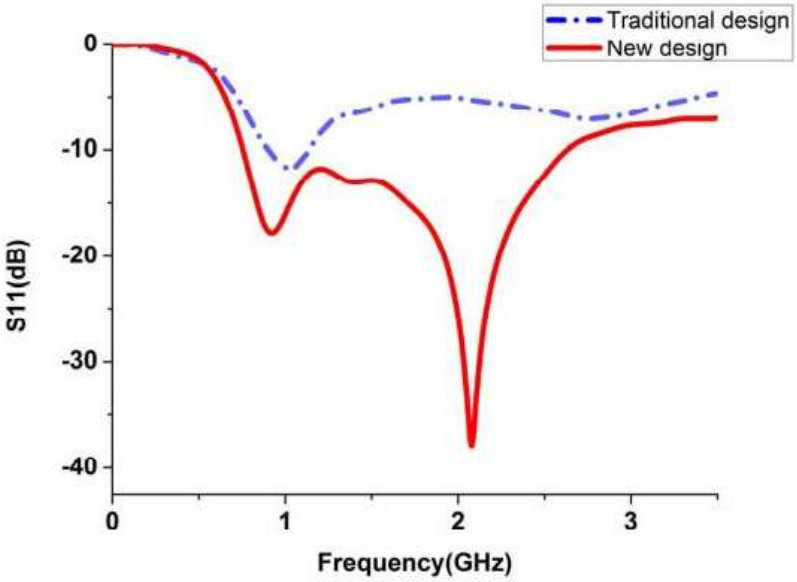


Figure 3. Reflection coefficient (dB) of the water antennas

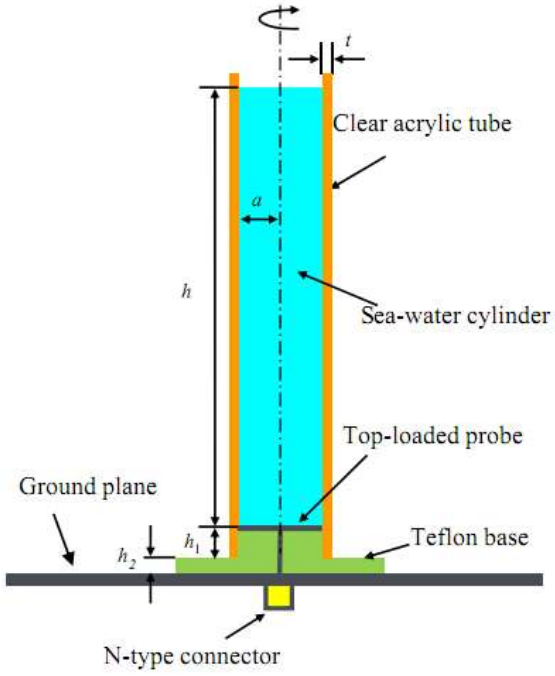
Bandwidth > 95% (0.8 ~ 2.56 GHz), Radiation efficiency > 50% (1.2 ~ 2.2 GHz)

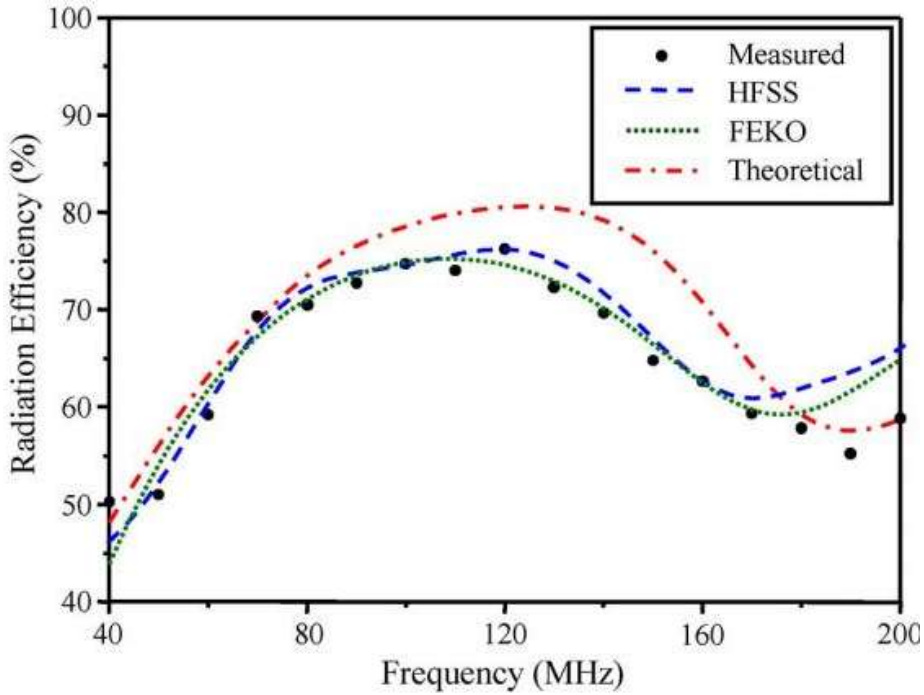
[2] L. Xing, Y. Huang, S. S. Alja'afreh, and S. J. Boyes, "A monopole water antenna," Loughborough Antennas and Propagation Conference, 2012, pp. 1-4.

I. Introduction (cont.)

Methods of improving radiation efficiency

- Load a disk on top of feeding probe
- Thick sea-water cylinder

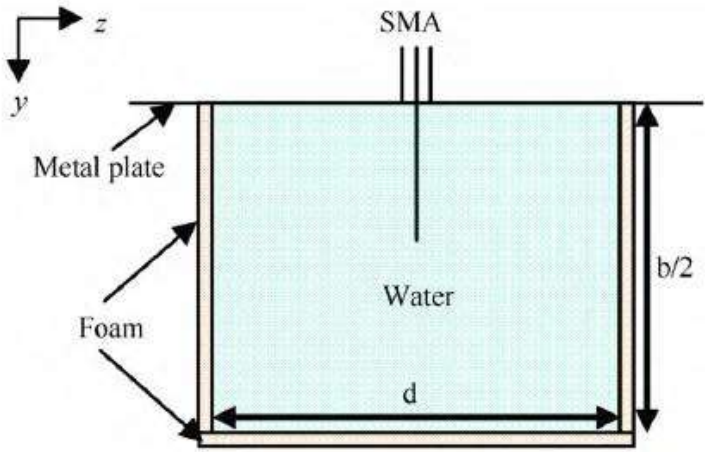




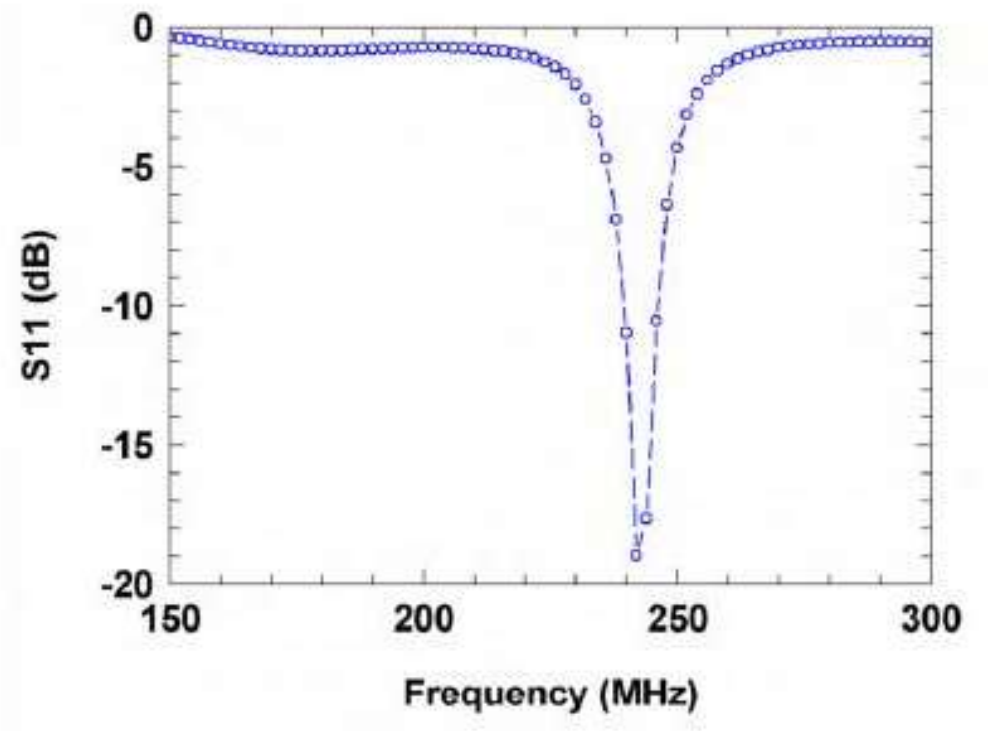
[3] C. Hua, Z. Shen, and J. Lu, "High-efficiency sea-water monopole antenna for maritime wireless communications," IEEE Trans. On Antennas and Propagation, vol. 62, no. 12, Dec. 2014.

I. Introduction (cont.)

Dielectric resonator water antenna



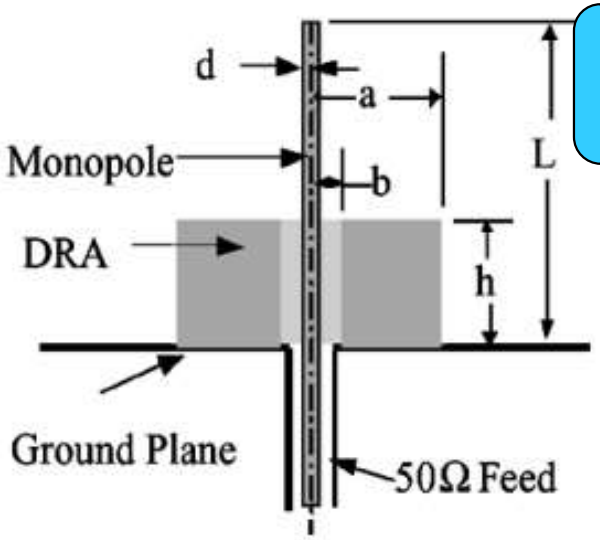
$TE_{21\sigma}{}^{z}$

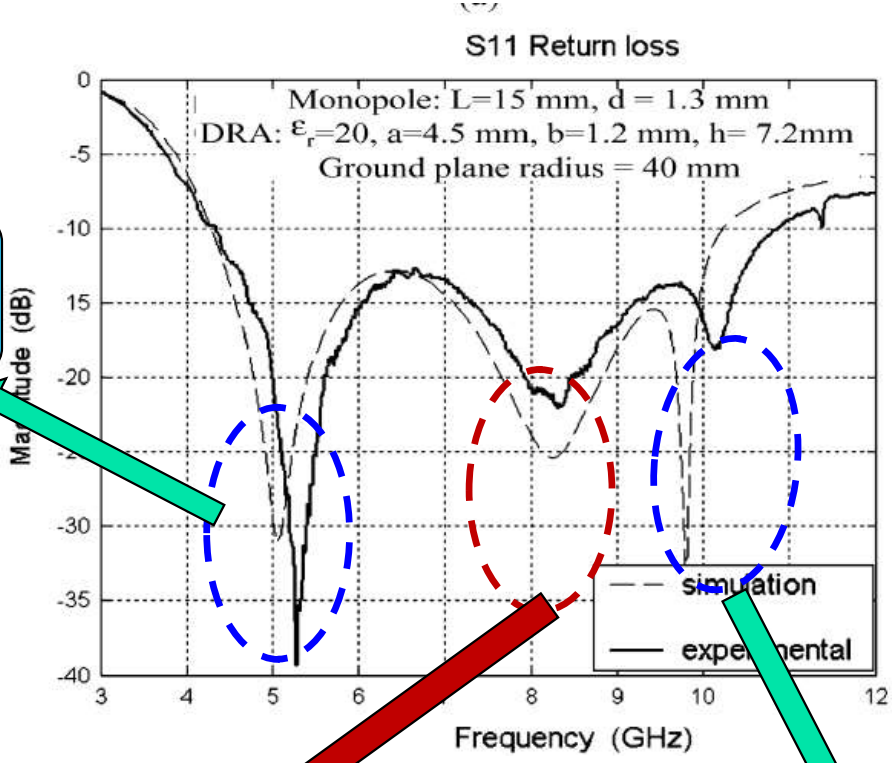


[4] R. Zhou, H. Zhang and H. Xin, "Liquid-based dielectric resonator antenna and its application for measuring liquid real permittivities," IET Microw. Antennas & Propag., vol.8, no.4, pp.255-262, 2014.

I. Introduction (cont.)

Hybrid solid Antenna





monopole resonance

DRA acts as a loading element on the monopole

DRA resonance

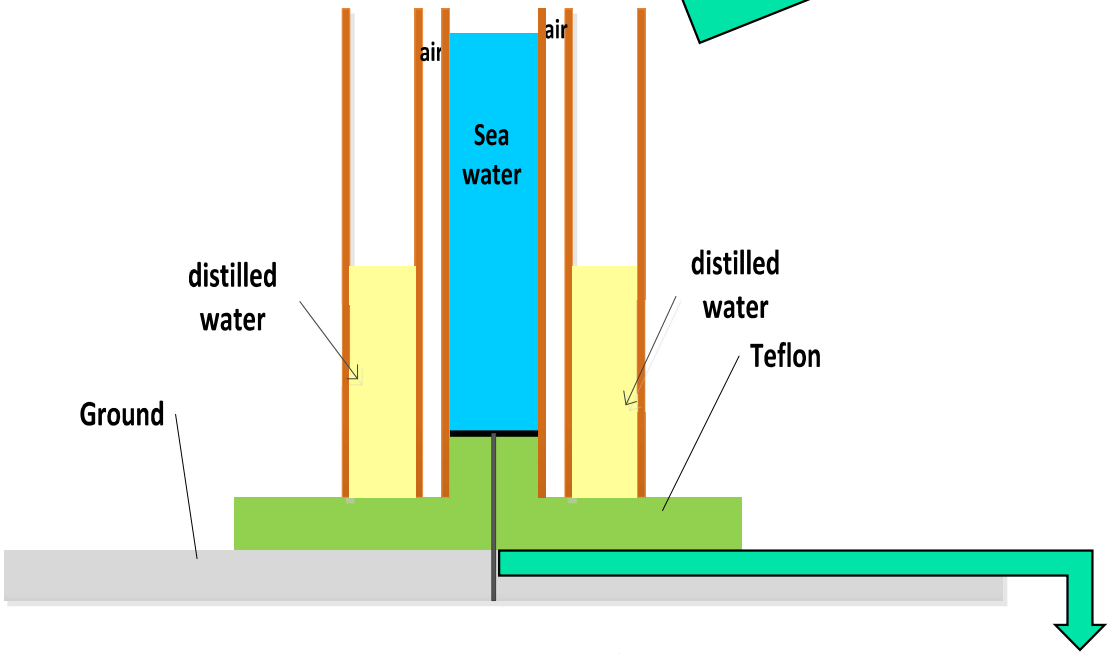
[5] M. Lapierre, Y. M. M. Antar, A. Ittipiboon, and A. Petosa , "Ultra wide-band monopole/dielectric resonator antenna," IEEE Microw. Wireless Comp. Lett. , vol. 15, no. 1, pp. 7–9, Jan. 2005.

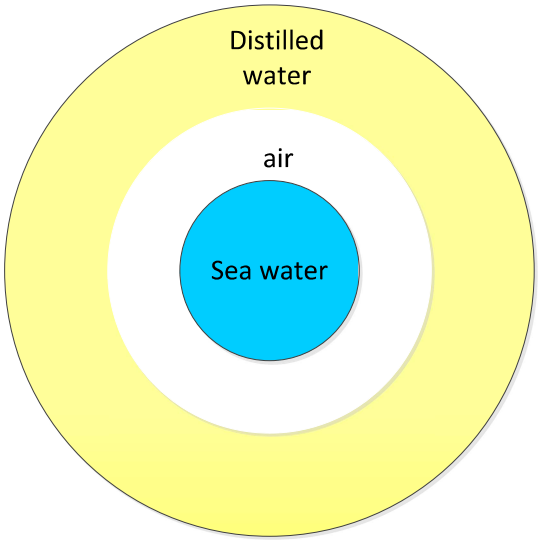
II. Design of Antennas

Antenna -1

different liquid materials

different types of antennas



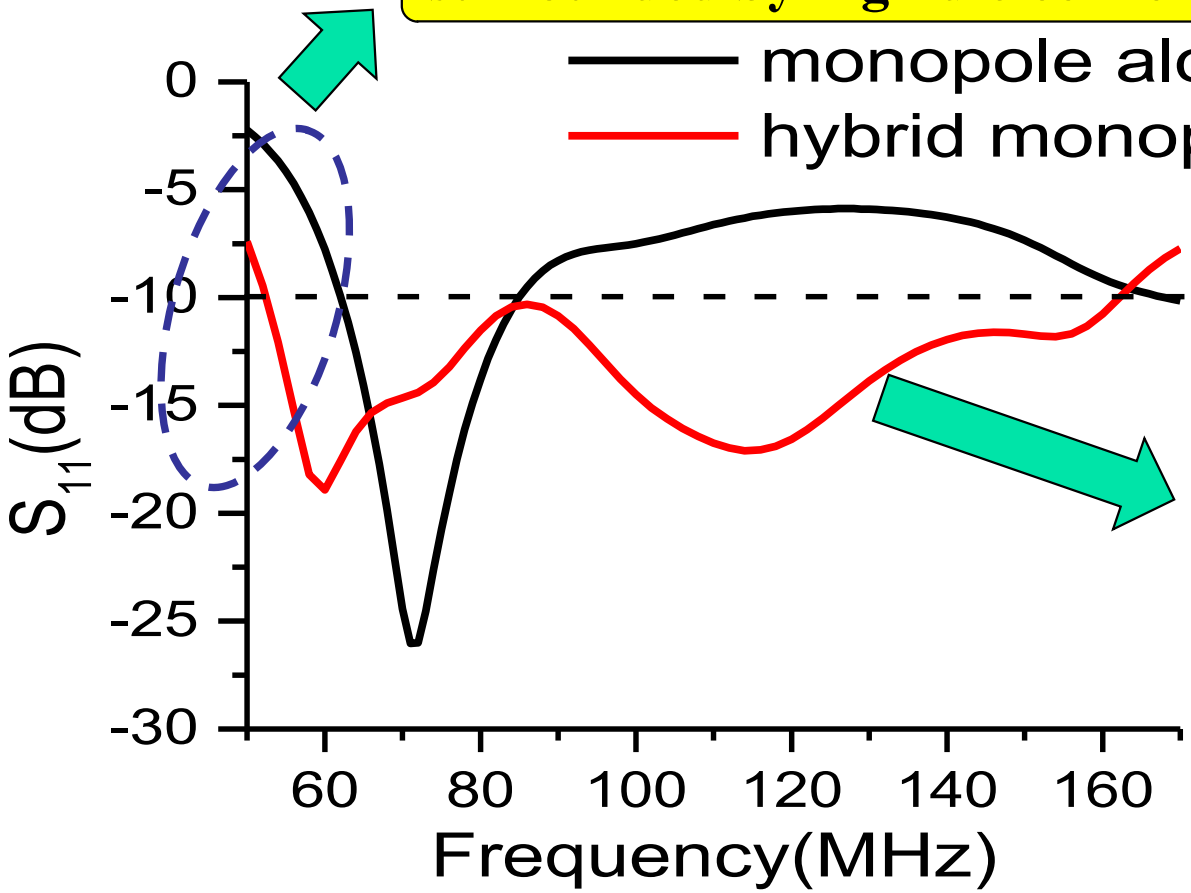


The feeding probe is loaded with a copper disk on top

II. Design of Antennas (cont.)

Simulation results

surrounded by high dielectric constant of medium

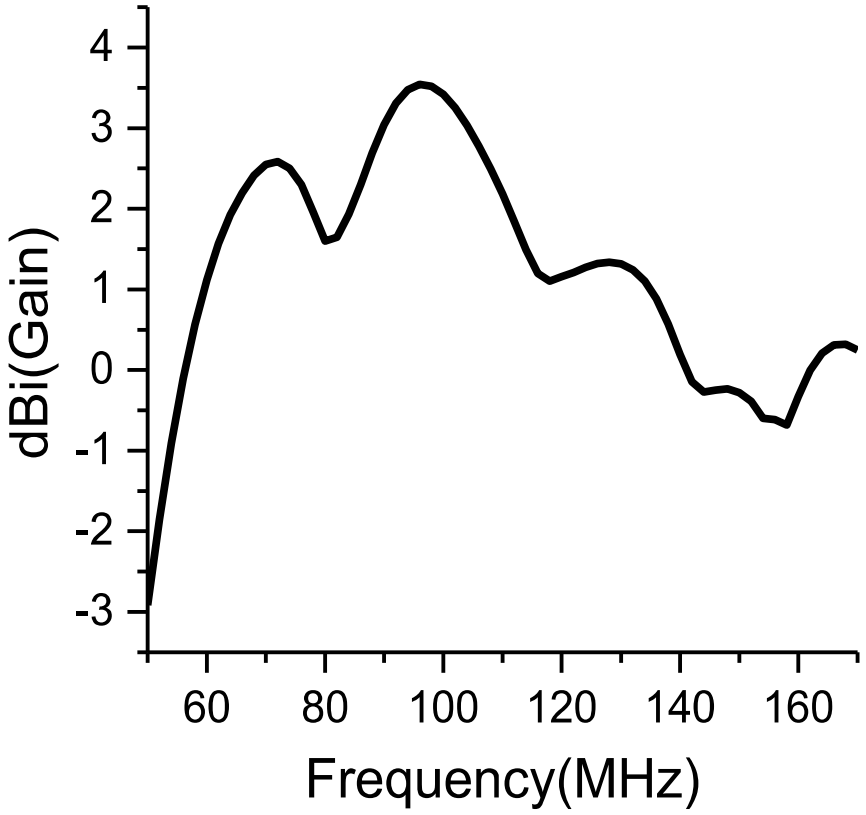


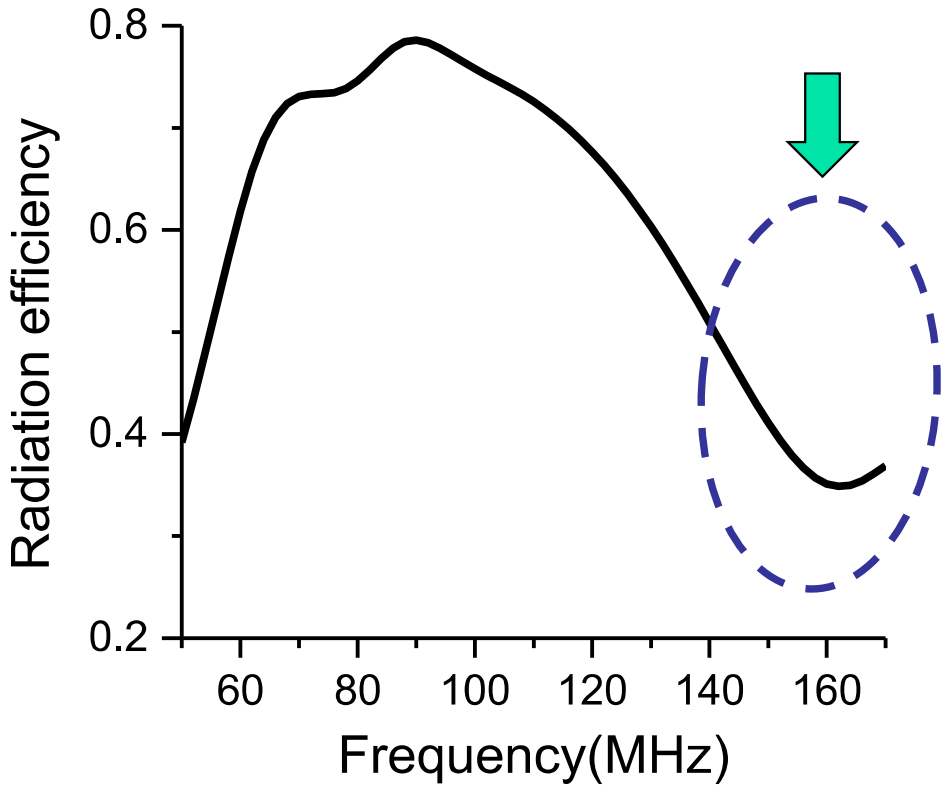
The broadband is caused by the multi-resonances introduced by the hybrid monopole - ring structure.

Bandwidth: 52.5 ~ 162.5 MHz(102%)

II. Design of Antennas (cont.)

Losses become larger at high frequency

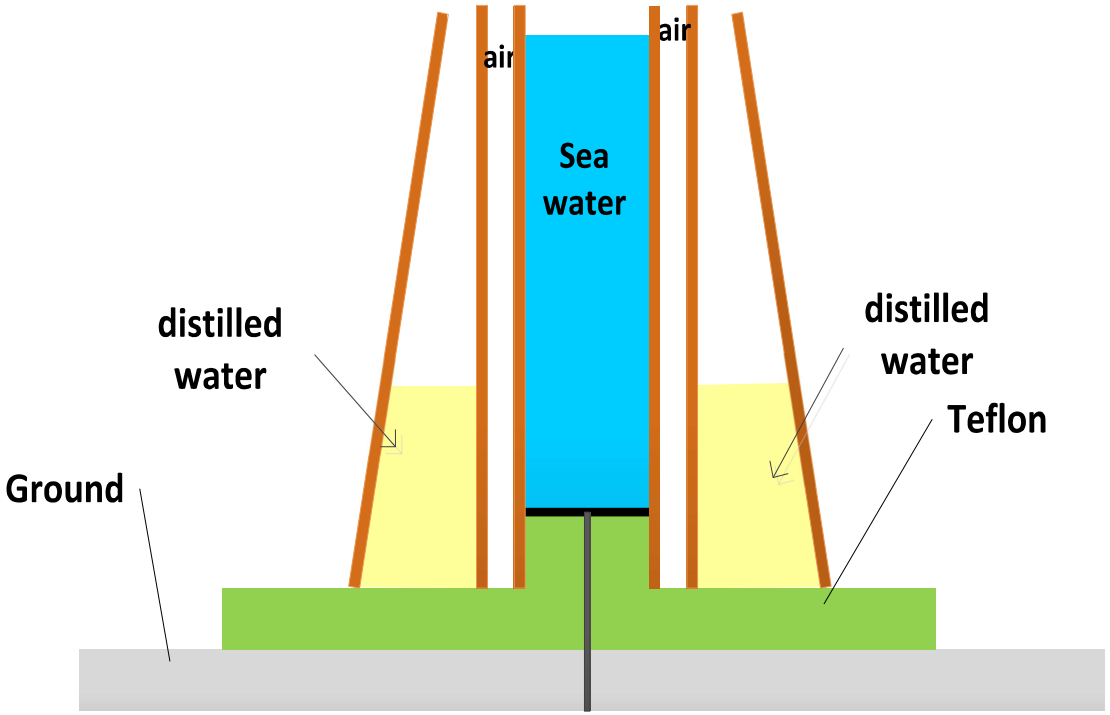


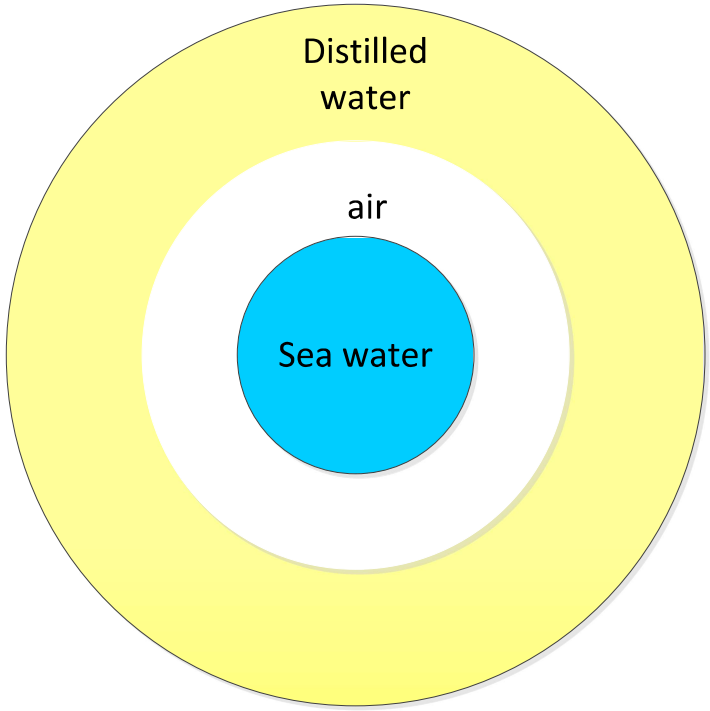


Radiation efficiency: 37% ~ 79%

II. Design of Antennas (cont.)

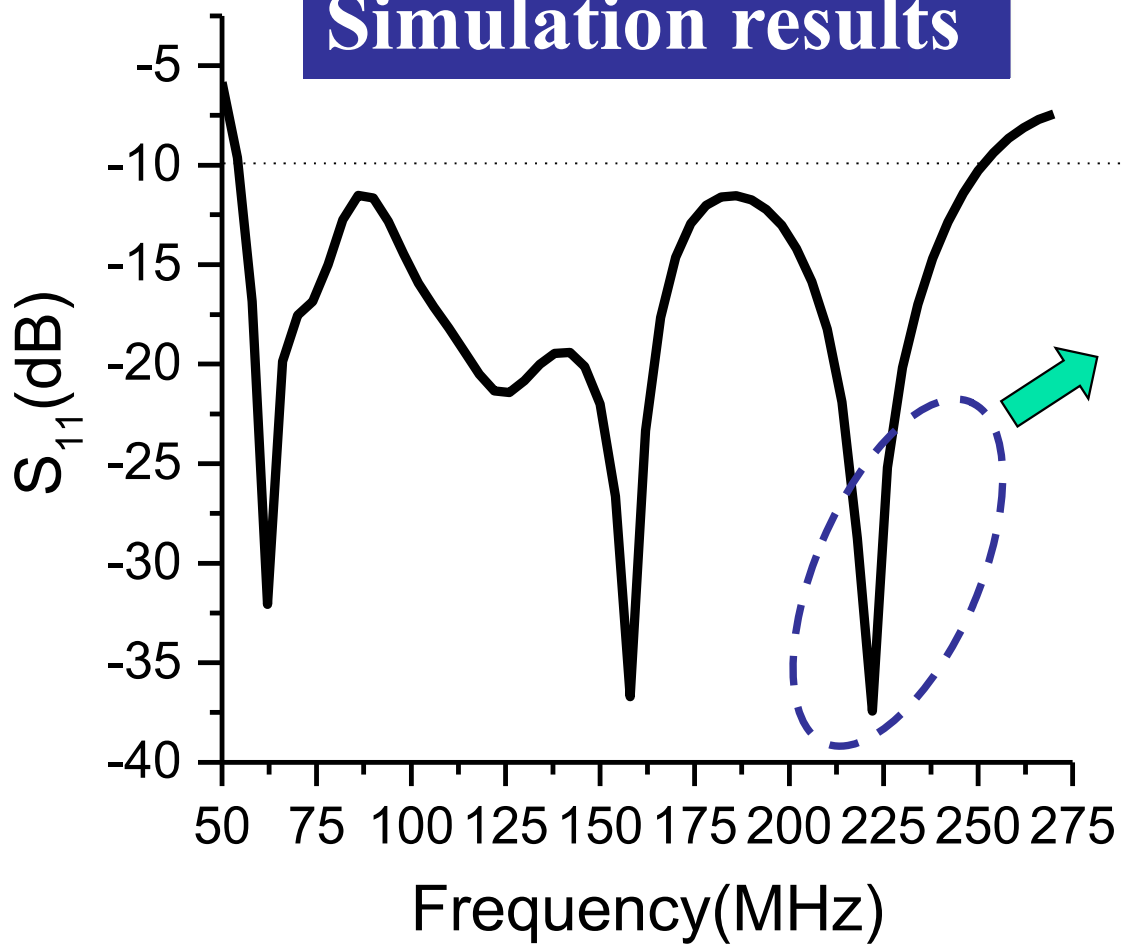
Antenna -2





II. Design of Antennas (cont.)

Simulation results

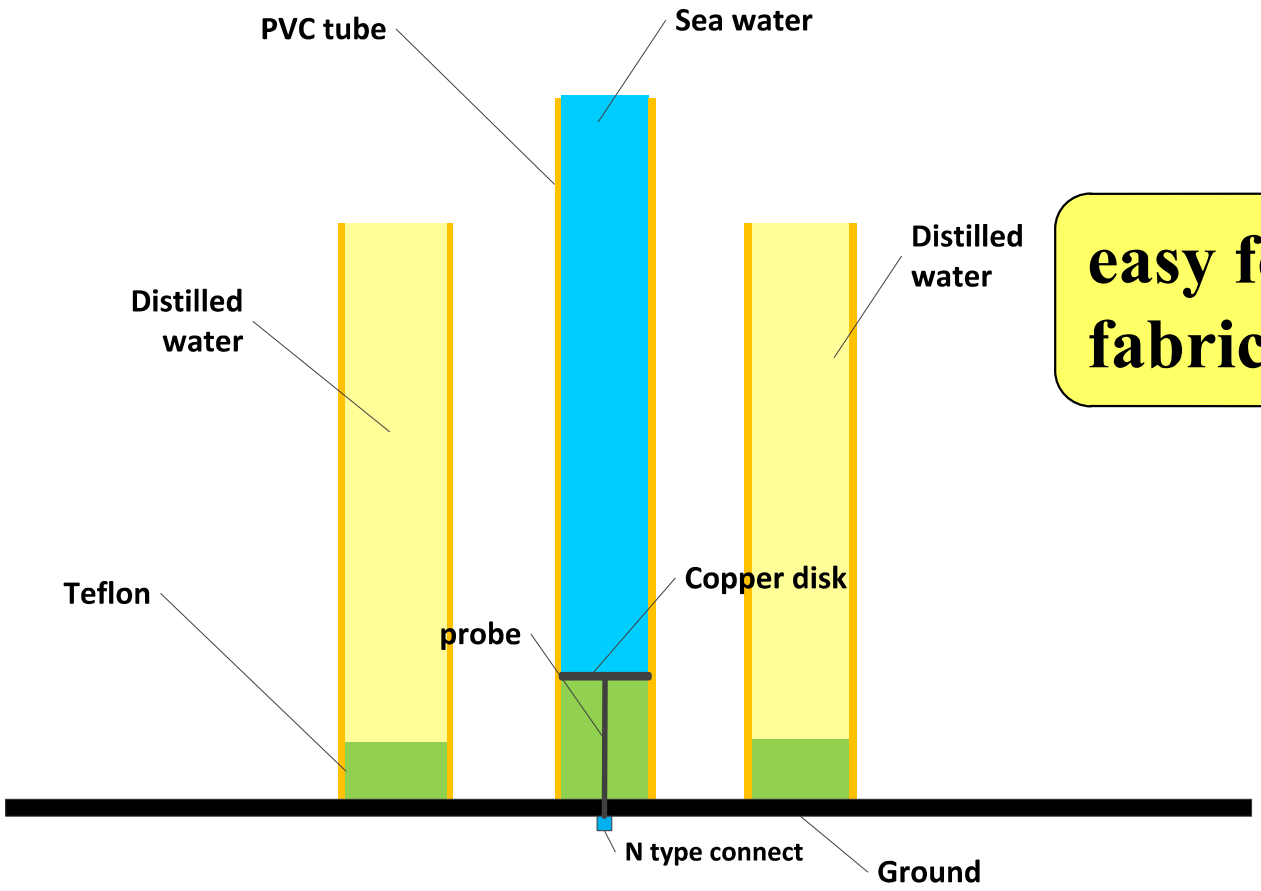


add an additional resonance

Bandwidth: 54.5 ~ 251.4 MHz (129%)

II. Design of Antennas (cont.)

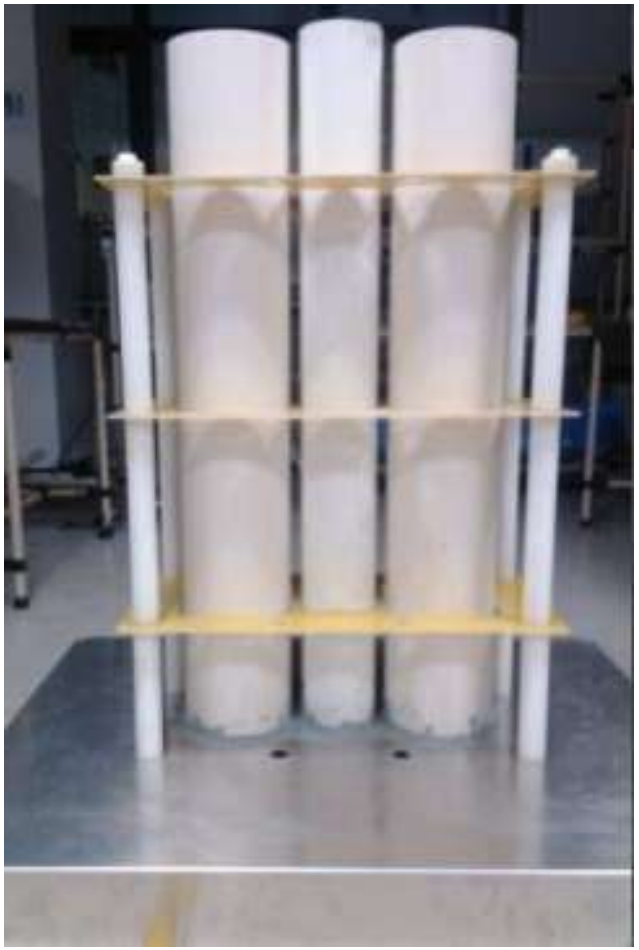
Antenna -3



easy for fabrication

II. Design of Antennas (cont.)

Antenna -3

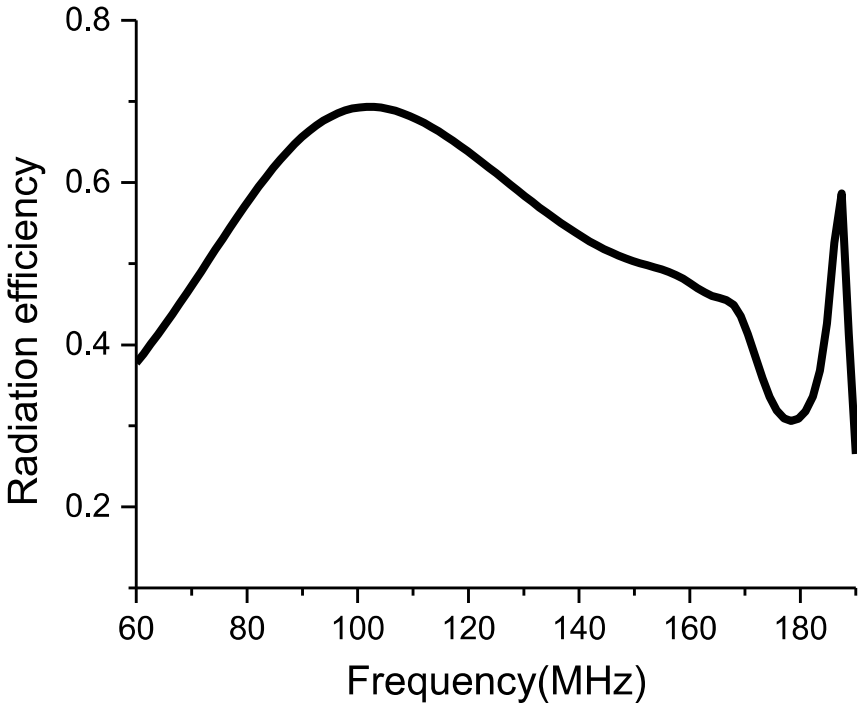


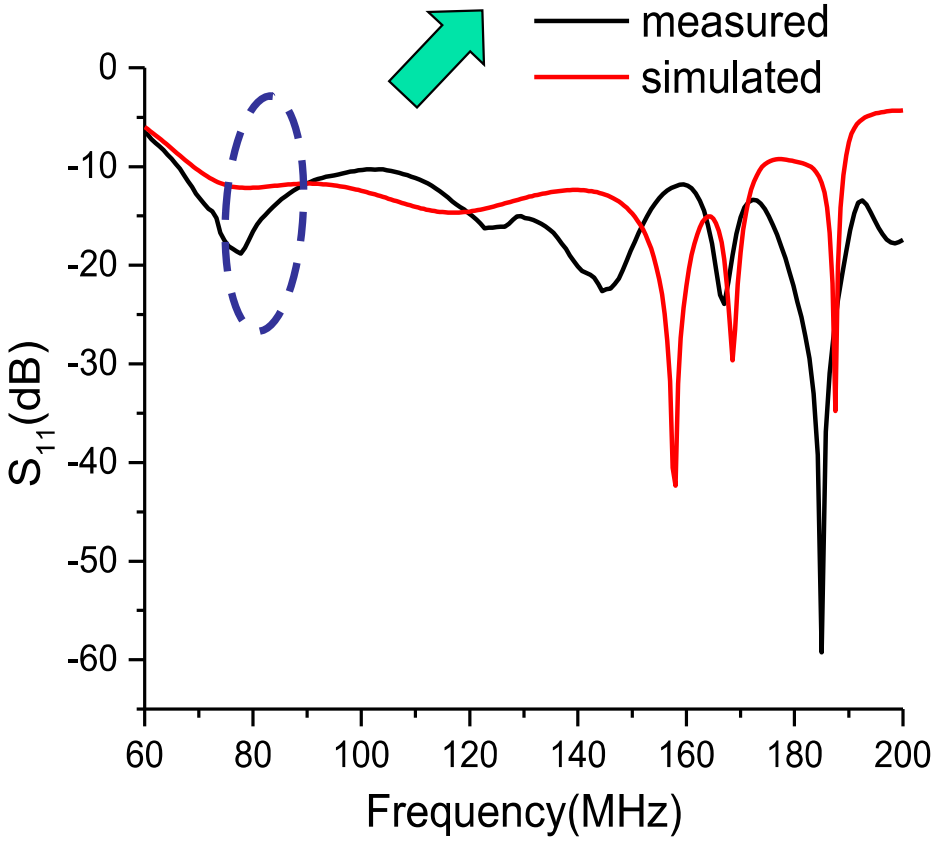
Photograph of the fabricated hybrid water antenna

II. Design of Antennas (cont.)

Results

The relative dielectric constant is changed

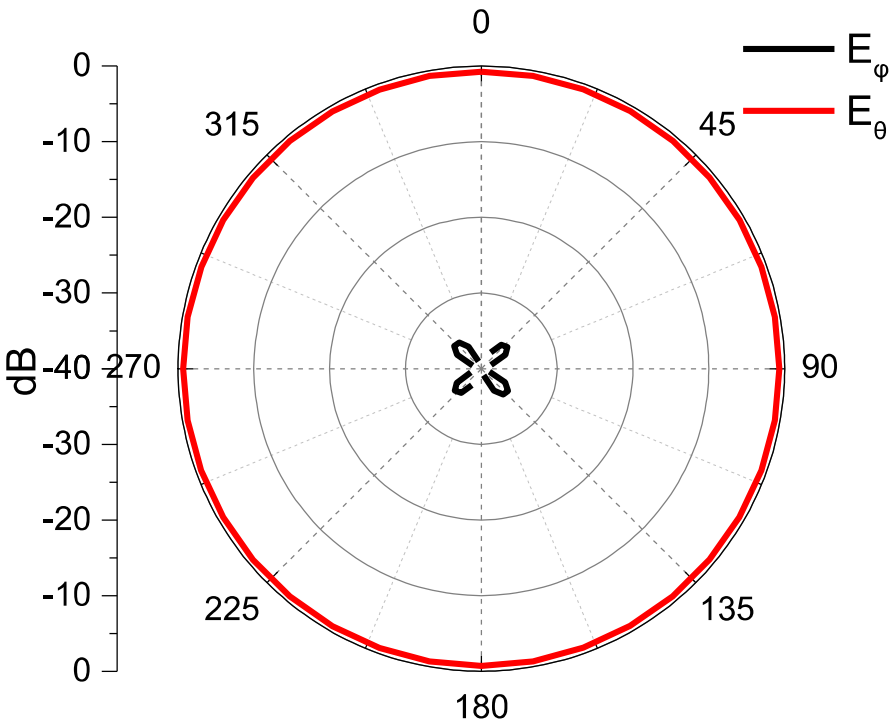




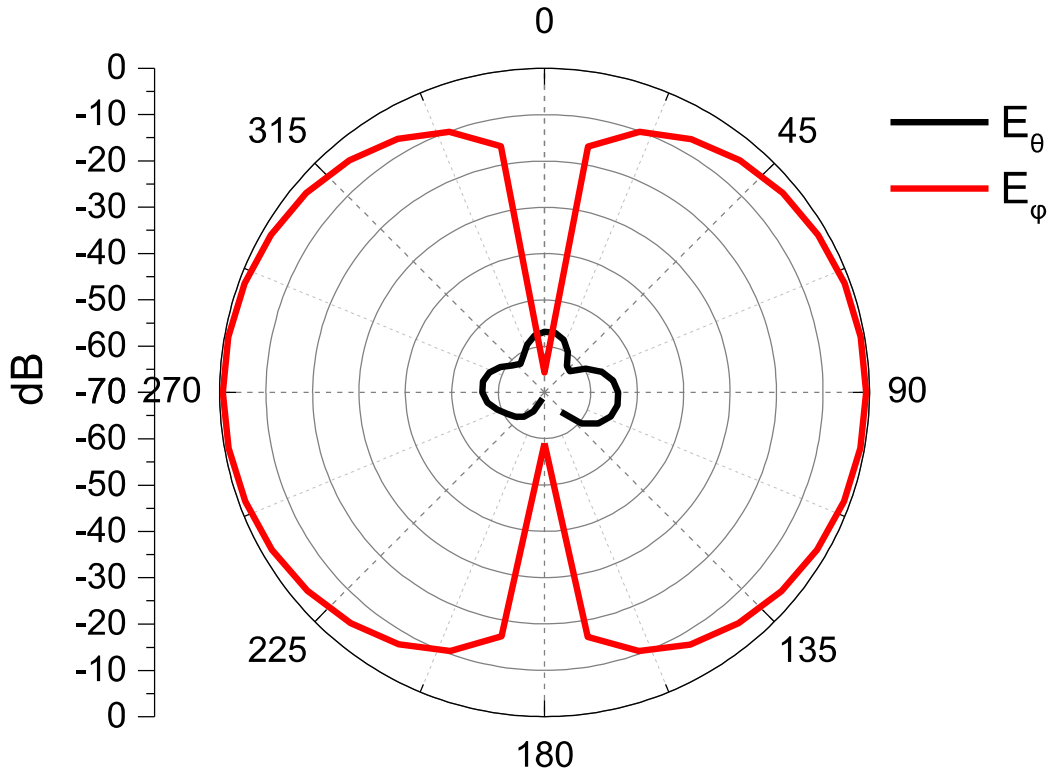
- **Bandwidth: ~90%(66 ~ 172 MHz)**
- **Radiation efficiency:>40%(66 ~ 170 MHz)**

II. Design of Antennas (cont.)

XOY

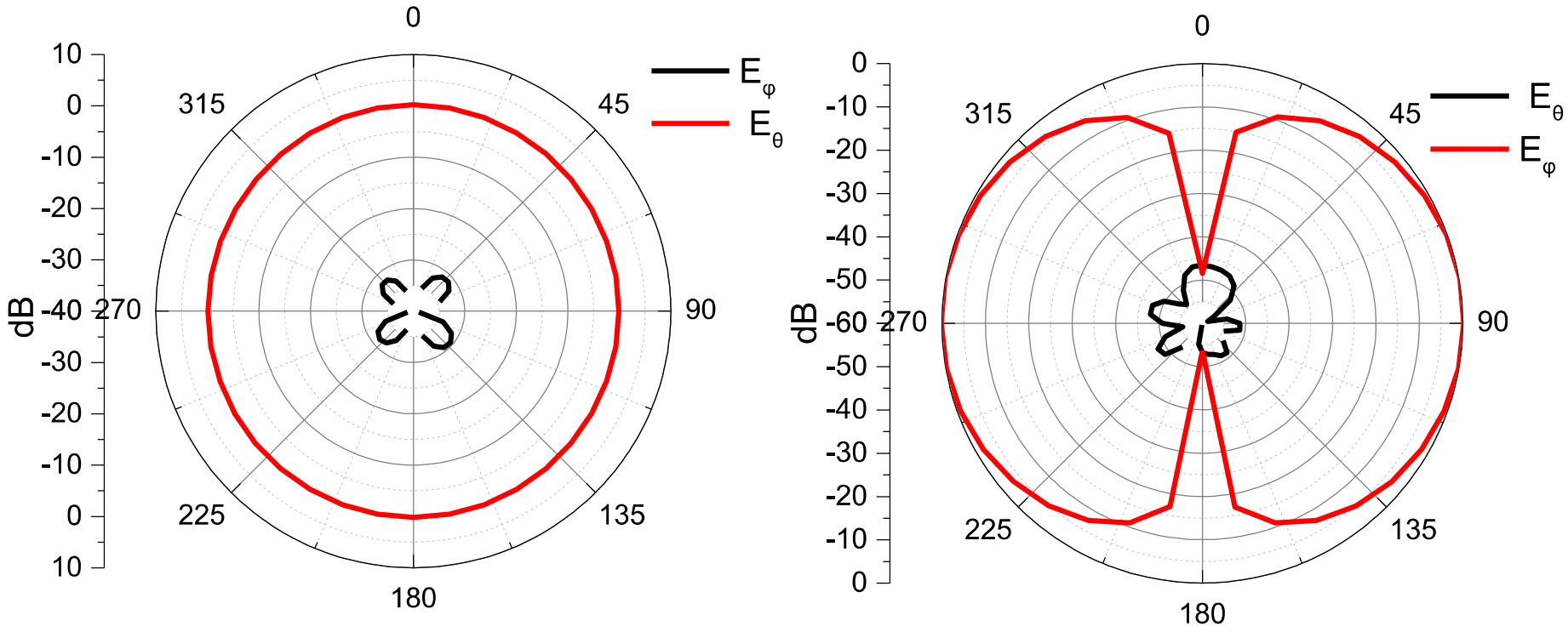


XOZ



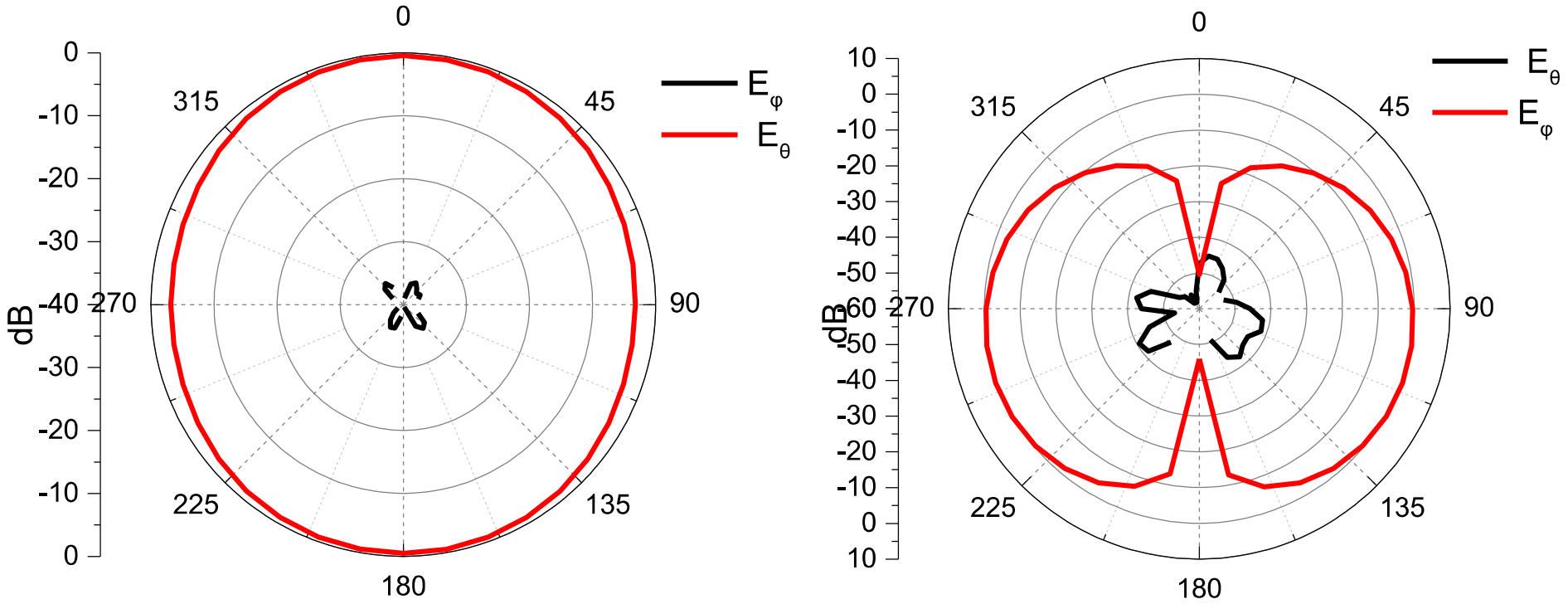
73MHz

II. Design of Antennas (cont.)



116MHz

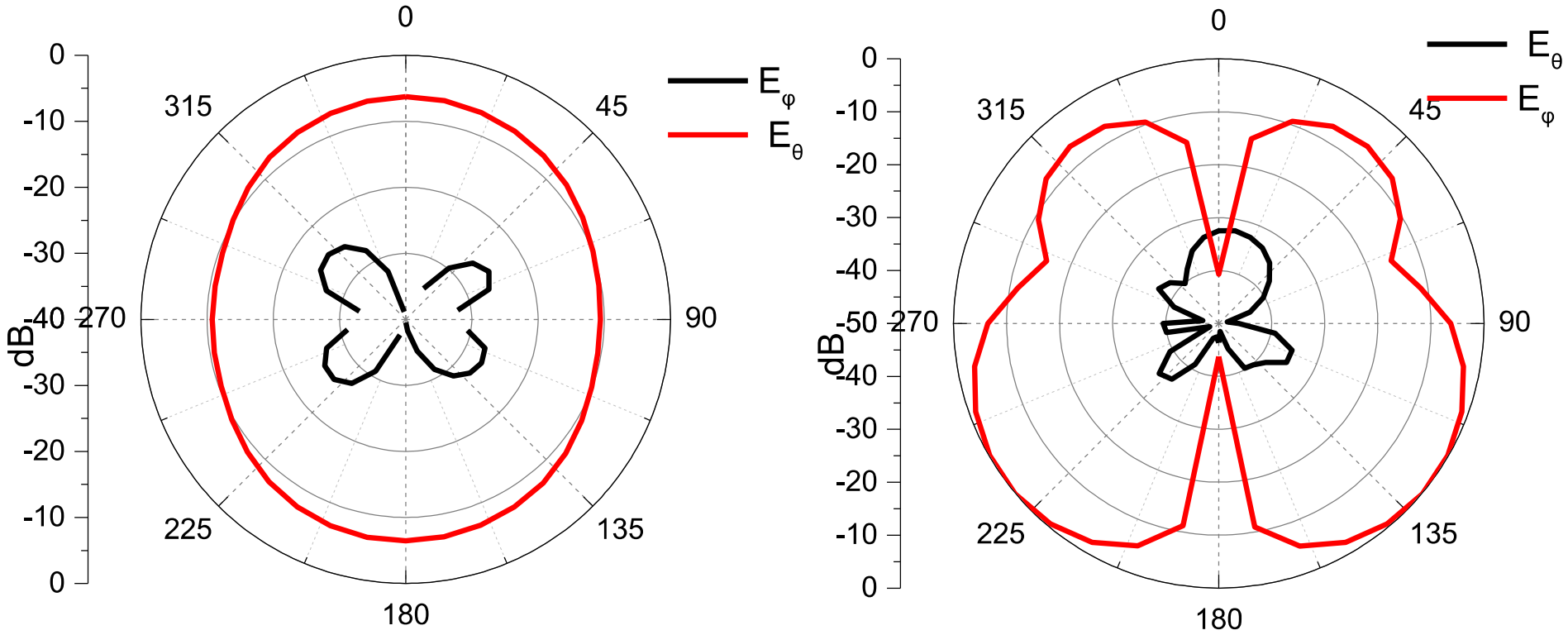
II. Design of Antennas (cont.)



157MHz

II. Design of Antennas (cont.)

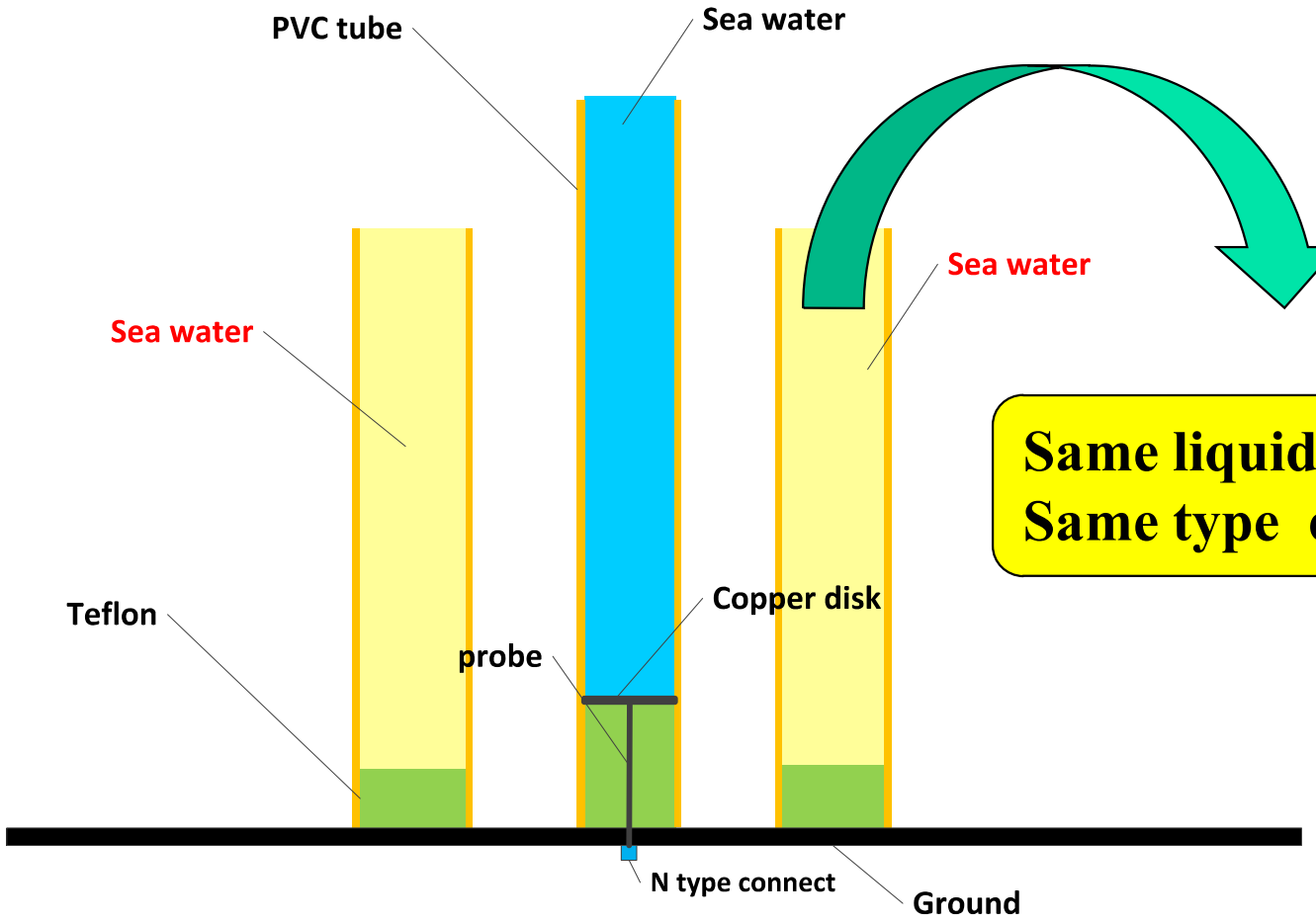
stable radiation patterns



168MHz

II. Design of Antennas (cont.)

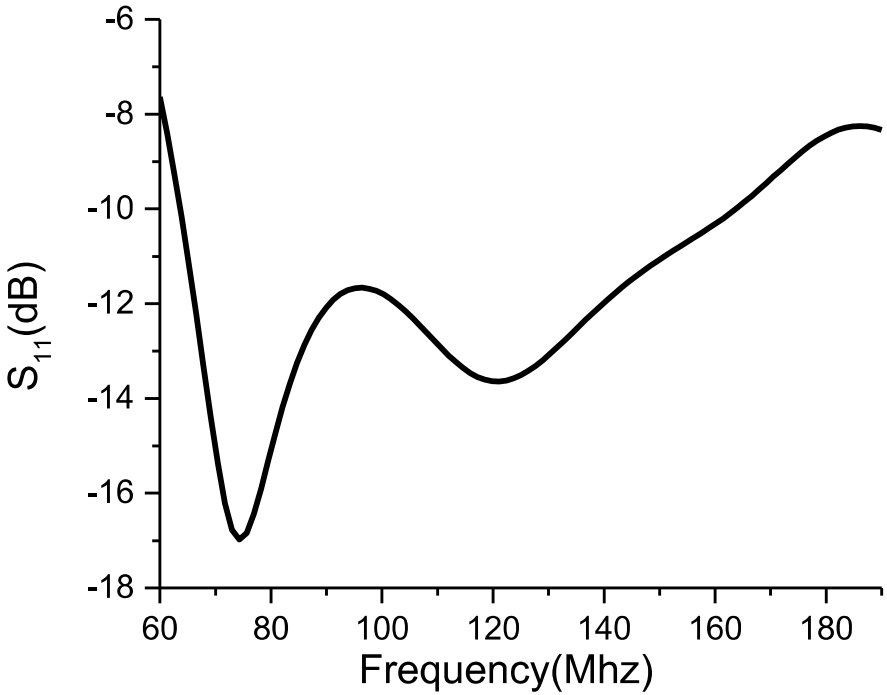
Antenna -4



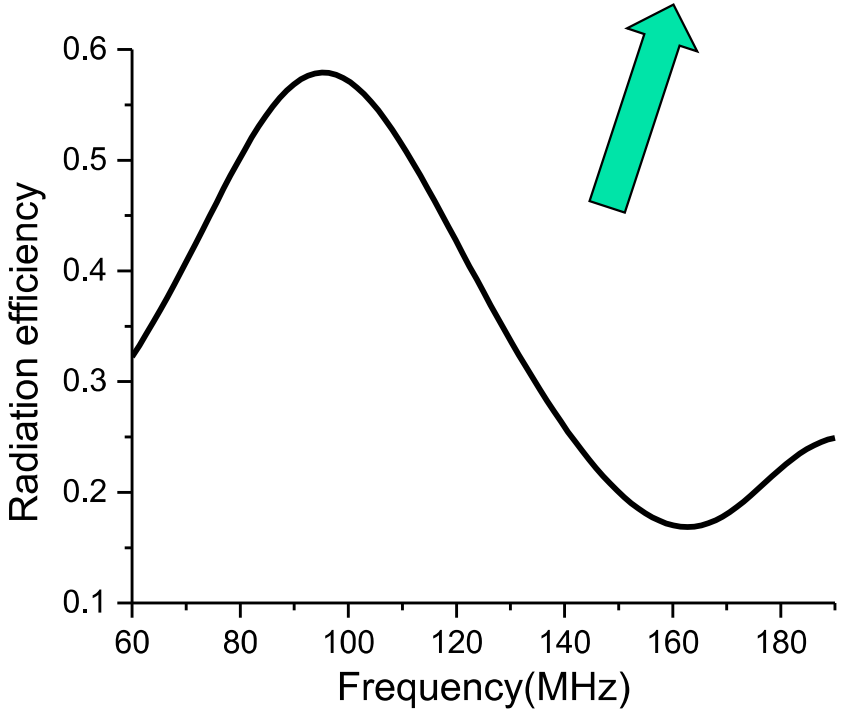
Same liquid material
Same type of antenna

II. Design of Antennas (cont.)

Simulation results



Low efficiency



The advantage of dielectric resonator loaded

IV. Conclusion

Structure

- Dielectric resonator antenna.
- Conductor monopole antenna.
- Dielectric layer.
- The feeding probe is loaded with a copper disk on top.

Operation

- Broad band.
- High efficiency.

Performance

- Stable radiation pattern.
- Be suitable for VHF wireless communications.

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THANK YOU